Evaluating concentration of aerosol particles in occupational hygiene using Optical Particle Counters

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Principles of direct reading aerosol measurement

- β - gauge method
- Piezoelectric method
- Tappered element method

Classical filter,
Automatic weighing

- Electrical mobility method
- Triboelectrical method

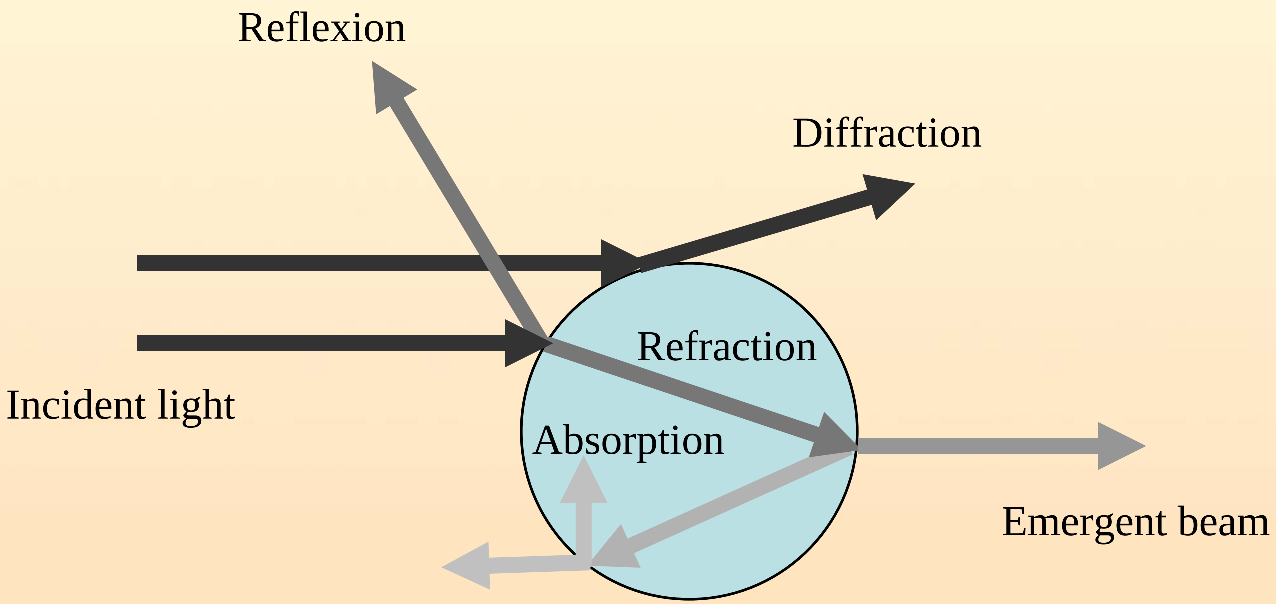
- **Optical Methods**

Optical methods

- Measurement of light transmission
  - Transmissionmeters

- Measurement of light scattering
  - Photometers
  - Optical Particle Counters (COP)

Light scattering



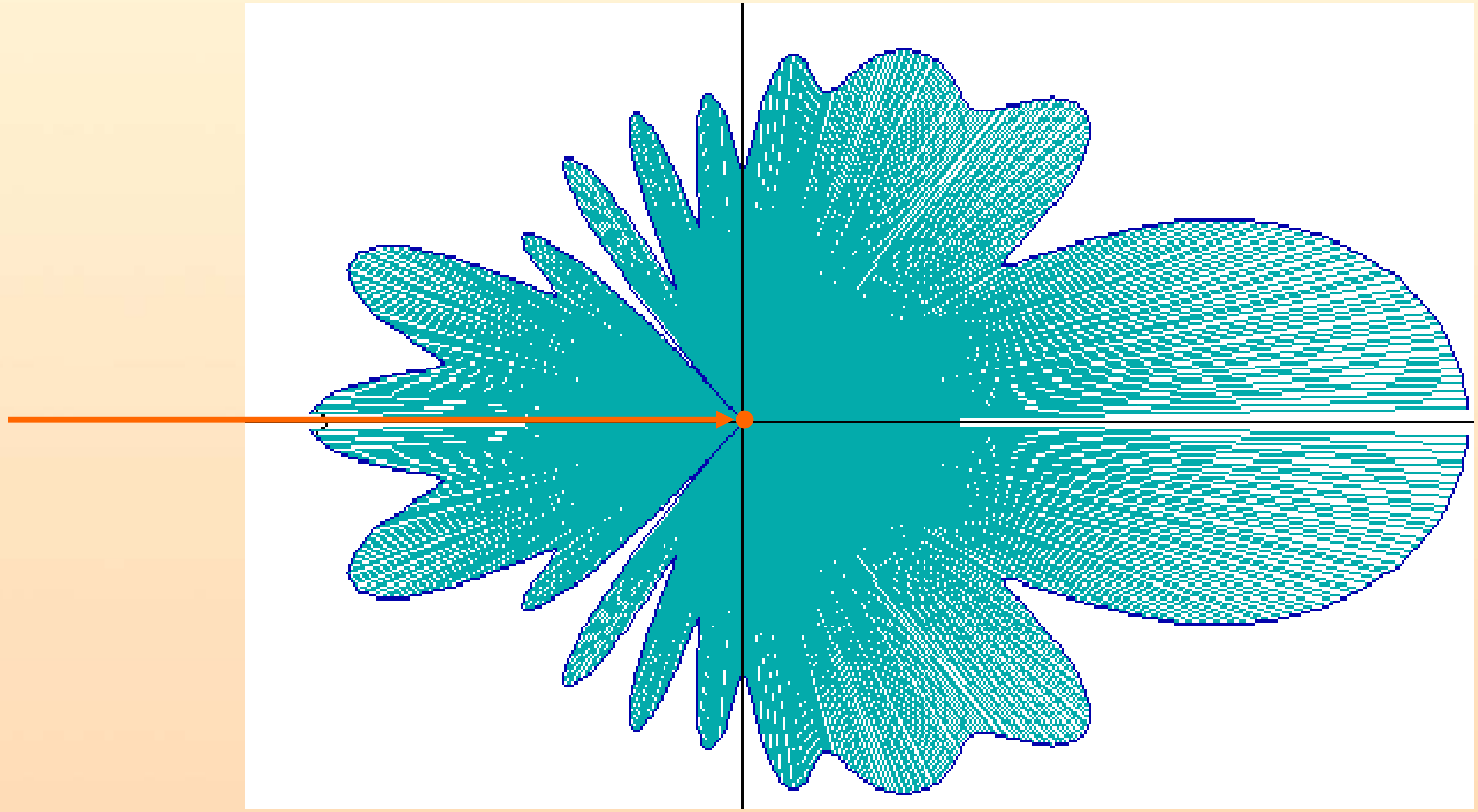
Mie's theory of scattered light (1908)

$$I = I_0 \frac{\lambda^2}{4\pi^2 \; L^2} \cdot \frac{i_1(\alpha, n, \theta) + i_2(\alpha, n, \theta)}{2}$$

I - Intensity of scattered light
I_o - Intensity of incident light
λ - Wavelength of light
L - Lenght
i_1, i_2 Intensity functions
n - Particle complex refraction index
α - Particle size parameter ($\pi d/\lambda$)
θ - Angle of scattered light observation

Spatial distribution of scattered energy

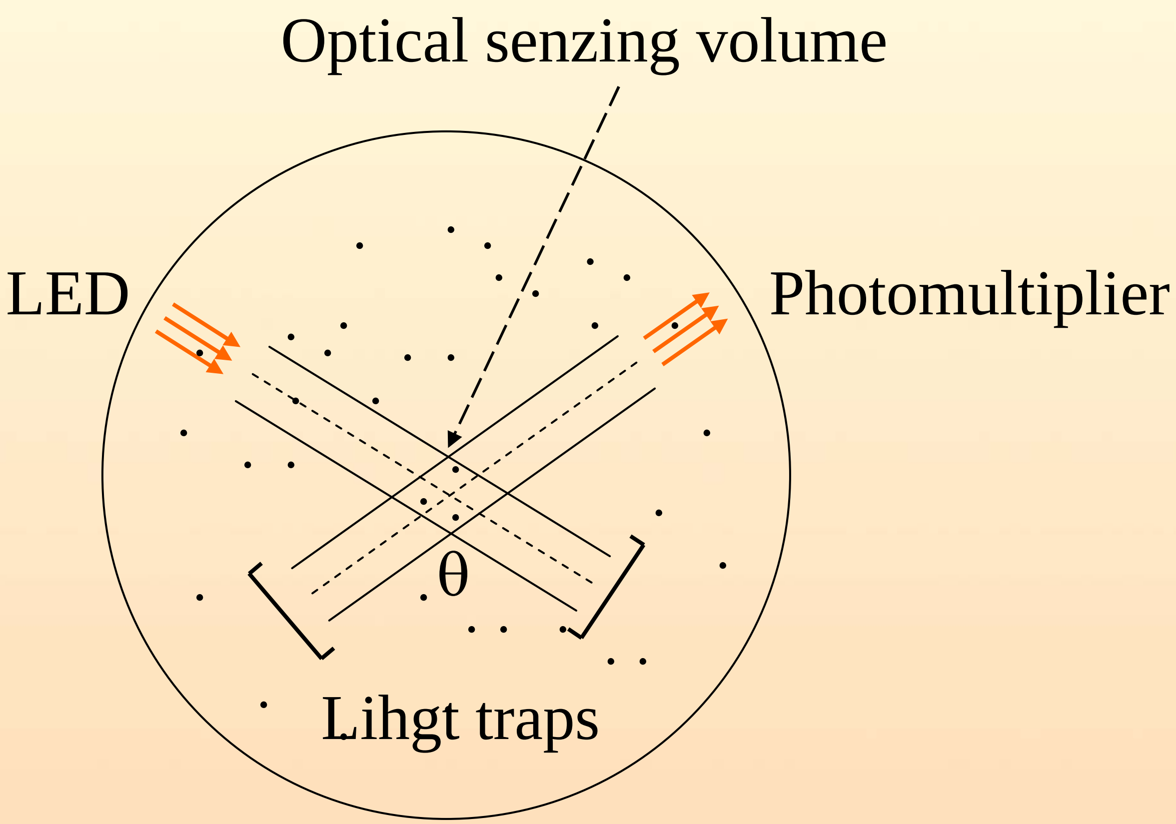
d=3 µm, n=1.5-0i, λ=960 nm, 0°< θ <360°



Apparatus to measure light scattered by airborne particles

- Photometers
- Optical Particle Counters (OPC)

Opticle cell of a photometer



Photometer does not measure any concentration

What does a photometer measure ?

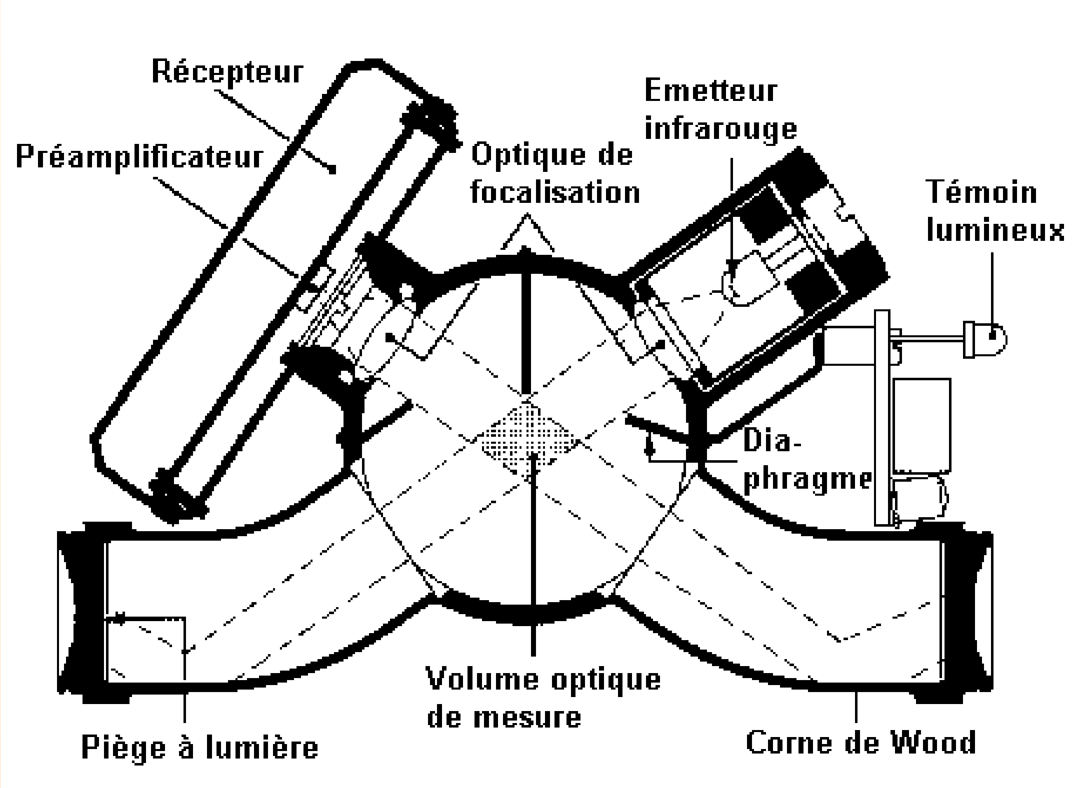
- I_o / I ratio for a particle cloud inside the optical senzing volume

- Need to be calibrated with a dust of the same n, ρ, and particle size distribution, as the measured aerosol

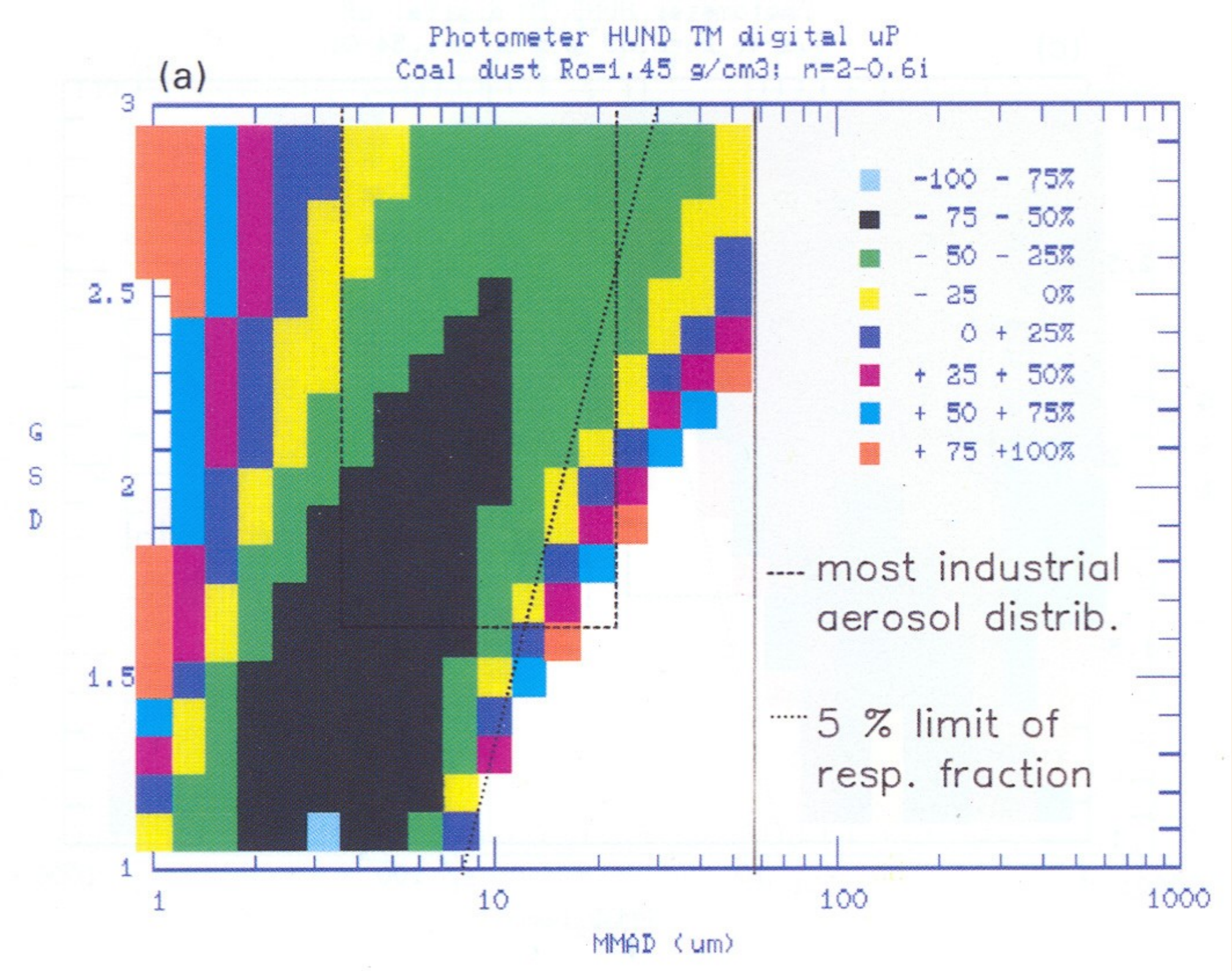
Photometer TM data (Hund, D)

Photometer HUND TM digital µP

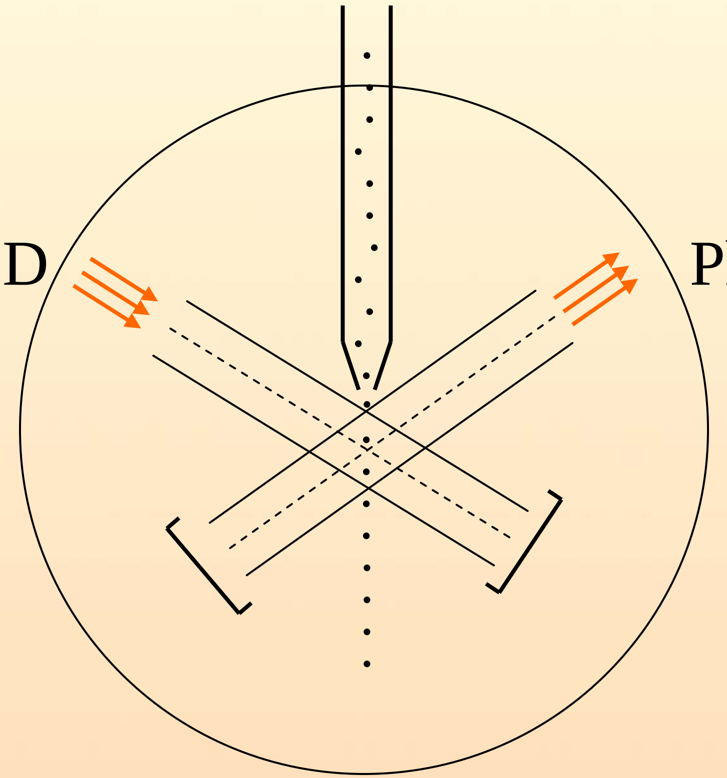
- Optical cell



Bias map of the photometer
(HUND TM digital µP)



Optical cell of a OPC



- OPC measures particle size resolved number concentration
(Limited at about 10^3–10^5 part./m^3)

Particle number concentration versus particle mass concentration

$$C_n\ [\mathrm{nbr.m^{-3}}] \longrightarrow C_m\ [\mathrm{mg.m^{-3}}]$$

COP response depends on: nbr, d, n

Mass concentration depends on: nbr, d, ρ

(n, ρ - particle ref. index and specific mass)

Calculation of particle mass

Particle mass of particle n_i with the diameter d_i is:

$$m_i = \sum n_i . \left(\frac{\pi . d_i^3 . \rho}{6} \right)$$

Total particle mass:

$$m = \Sigma m_i$$

Conditions:

Particles are spherical with unique and known density ρ

Optically measured diameter equals the geometric d

Calculation of health-related aerosol fractions

$$C_f = C_T \int_0^\infty P_{t,r}(d_{ae}) \cdot F_m(d_{ae}) \cdot d\, d_{ae}$$

$d_{ae} = d\,(\rho/\rho_o)^{1/2}$ where $\rho_o = 10^3$ kg.m^{-3}
(for spherical particles)

Standard NF X43-299, Technical Report CEN

Practical exemple

INRS Inhalable sampling head

Internal calibration filter

GRIMM 1.1 OPC

OPC: Grimm 1.108
Inhalable aerosol sampler CIP 10-I
Respirable aerosol sampler CIP 10-R

Sampling in Sausage factory. Activity: « Brushing – Coating » and packaging
Aerosol : Fungi spores ($\rho_p \approx 1000$ kg.m^{-3}) and carbonate of calcium ($\rho_p \approx 2700$ kg.m^{-3})
Aerosol particle size-distribution in mass : MMAD≈8.75 µm ; GSD≈2.15

Sampling				$\overline{C_N}$	$\overline{C_M}$ (calculation from $C_{N,i}$ by classes of dp$_i$)					CIP 10-I Inhalable fraction	CIP 10-R Respirable fraction
Date	Start	End	Activityr		Particles are supposed to be spherical / Particle specific mass						
					$\rho_p \approx 1000$ kg.m^{-3}	$\rho_p \approx 1340$ kg.m^{-3}			$\rho_p \approx 2700$ kg.m^{-3}		
				part.L^{-1}	mg.m^{-3}	mg.m^{-3}			mg.m^{-3}	mg.m^{-3}	mg.m^{-3}
05/02/2008	7h30	14h47	Brushing – Counting	637125	12,1	**16,2**	11.0	**3.8**	32,7	**16,5 ± 0,8**	**3,4 ± 0,2**
06/02/2008	7h32	15h18	Packaging	208455	3,1	**4,2**	2.8	**1.0**	8,4	**4,1 ± 0,2**	**0,76 ± 0,04**
					Inh	**Inh**	Thor	**Res**	Inh	**Inh**	**Res**

Grimm terminal filter Particle mass after 2 days sampling: 12,117 mg (INRS sampling head mounted on Grimm)
Air volume sampled in two days : 520 L (05/02/2008) + 560 L (06/02/2008) = 1,080 m^3

Average for two days

$$\overline{C_{M,Grimm}} = \frac{12,117}{1,080} = 11,2 \text{ mg.m}^{-3} \longleftrightarrow 10,1 \pm 0,5 \text{ mg.m}^{-3}$$

Limitations

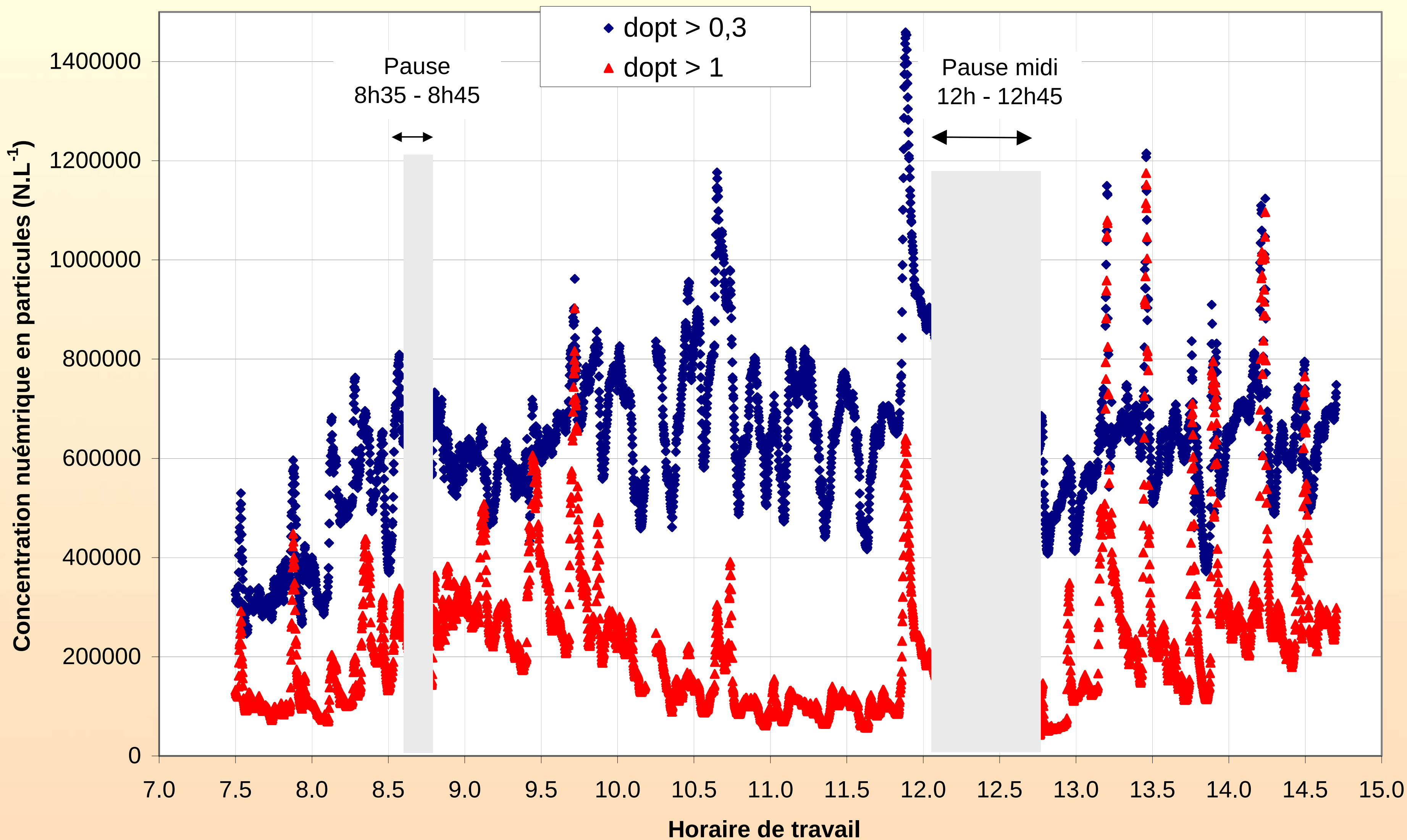
- Particle sphericity, $d_o = d_p$
- Sensibility on particle optical properties
- Unsensibility to particle density
- Necessity of in situ calibration
- Zero check
- Water haze

Advantage of using OPC in occupational hygiene

- Direct reading measurement
- Time resolved concentration profile
- Possibility of workplace mapping

- Measurement of particle size

COP - Grimm® 1.108



Time resolved concentrations for particles of two differerent sizes

Brushing–coating operation in sausage factory

The END